CALCULATION OF AIR ACTIVATION ACTIVITY FROM TA-18

Purpose

This Meteorology and Air Quality group (MAQ) procedure describes the steps to calculate the activity resulting from activation of air due to operations at TA-18 (Los Alamos Critical Assembly Facility).

Scope

This procedure applies to the calculation and reporting of the air activation activity resulting from operations at the TA-18 site and reported as required by 40 CFR 61 (Rad-NESHAP).

In this procedure

This procedure addresses the following major topics:

Hazard Control Plan

The hazard evaluation associated with this work is documented in HCP-MAQ-Office Work.

Signatures

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04/15/03

02/02/04

General information about this procedure

Attachments

This procedure has the following attachments:

Number	Attachment Title	No. of pages
1	Description of Dose Calculation Assumptions and Methodology	2
2	Example Spreadsheets for Calculating Air Activation Dose	4

History of revision

This table lists the revision history and effective dates of this procedure.

Revision	Date	Description Of Changes
0	4/23/98	New document.
1	7/30/98	Correction scientific notation in steps 2 and 5 on p. 4, and Attachment 1. Correct values for calculation of activity for Godiva on p. 4 of Attachment 2.
2	3/9/00	Correct non-substantive errors. Change training method to self-study.
3	5/7/03	Quick-change addition of alternate conversion factor.

Who requires training to this procedure?

The following personnel require training before implementing this procedure:

- MAQ employee assigned to calculate the direct radiation dose from operations at TA-18

Training method

The training method for this procedure is "**self study**" (reading) and is documented in accordance with the procedure for training (MAQ-024).

General information, continued

Definitions specific to this procedure

None.

References

The following documents are referenced in this procedure:

- MAQ-024, "Personnel Training"
- Memo ESH-4-MTS-96:081, "Monte Carlo Calculation of Neutron Activation of Air Molecules," to Distribution from Hsiao-Hua Hsu, through Thomas Buhl, August 5, 1996

Note

Actions specified within this procedure, unless preceded with "should" or "may," are to be considered mandatory guidance (i.e., "shall").

Calculating air activation at TA-18

Assessment of air activation at TA-18

Diffuse emissions of activated air products are produced by the interaction of neutrons (produced by TA-18 criticality experiments) with the ambient air. The air activation dose equivalent at TA-18 cannot be measured directly around TA-18. The method used relies on the calculation of neutron emissions by knowing the temperature rise (for Godiva IV and SKUA assemblies) or the amp-sec of power (for the SHEBA assembly). The basis of the method is explained in Attachment 1.

Steps to calculate air activation

To calculate the activity from air activation products resulting from criticality exposures, perform the following steps:

Step	Action
1	Obtain from the facility manager or appropriate principal investigator at TA-18 a list of the criticality events that occurred over the past year or other time interval. The list must include the energy of each event. **NOTE**: The energy will be reported in units of ΔT or amp-sec.
2	Determine the estimated number of fissions produced in each burst by multiplying the energy by the number of fissions per unit of energy. The conversion factor of **total fissions = 1.85E+14 fissions** × **ΔT** or **8.0E+18 x amp-sec** for the GODIVA IV and SKUA assemblies and the **total fissions = 2.7E+18** × **amp-sec** for the SHEBA assembly for each event. Confirm with the facility manager or principal investigator at TA-18 that these conversions are still valid for the newly-obtained data. See Attachment 1 for guidance.
3	Determine the estimated number of neutrons by multiplying the number of fissions by 2.5 neutrons/fission. Sum the total number of neutrons produced in one year from all critical assemblies.
4	Calculate the total number of ^{41}Ar atoms using the conversion factor of **9.04E-05 ^{41}Ar atoms/neutron** for GODIVA IV and SKUA and **7.72E-05 ^{41}Ar atoms /neutron** for SHEBA.
5	Calculate the total annual ^{41}Ar Activity in units of curies by using the following formula: A (Ci) = [Atoms ^{41}Ar × decay constant (1.06E-04 sec^{-1})]/3.7×1E+10 dps/Ci See Attachment 2 for an example.
6	Ensure all analyses and calculations are peer reviewed by a health physicist working for the Rad-NESHAP project. Document the peer review.

Calculating air activation at TA-18, continued

Step	Action
7	Prepare a summary of all data used in the calculations and document the process assumptions that were used when this procedure was followed. Document any steps that were not followed or other deviations from the specified process. The level of documentation should be sufficient to allow duplication of the process. Submit the summary to management and a copy to the records coordinator.
8	Report this activity to the Rad-NESHAP project leader for calculation of dose and inclusion in the annual compliance assessment to EPA.

Records resulting from this procedure

Records

The following records generated as a result of this procedure are to be submitted as records **within two weeks of completion** to the group records coordinator:

- summary of all data used in calculations, explanatory information, and final results obtained

Click here to record "self-study" training to this procedure.

DESCRIPTION OF DOSE CALCULATION ASSUMPTIONS AND METHODOLOGY

The critical assemblies at TA-18 are named GODIVA IV, SKUA, and SHEBA. The energy for GODIVA IV and SKUA is measured in **ΔT,** the temperature change within the assembly during a critical experiment. The energy for SHEBA is measured in **amp-sec**. The following conversion factors were used to estimate the air emissions resulting from annual operations.

The principal investigator at TA-18 provided a conversion factor for GODIVA AND SKUA of

1.85E+14 fissions $\times$ ΔT

For every 54°C temperature change, 10^{16} fissions are produced. Confirm that this conversion factor is still valid for the data being evaluated. An alternate conversion factor for Godiva is 8.0 x 10^{18} fissions / amp-sec.

The principal investigator at TA-18 provided a conversion factor for SHEBA of

2.7×10^{18} fissions / amp-sec.

A conservative conversion factor used for neutron production was

 # neutrons = (# fissions) $\times$ (2.5 neutrons / fission)

Actual measurements indicate fewer neutrons per fission, some of which are absorbed in the fuel to sustain a chain reaction or in the structural material surrounding the assembly.

Because accurately measuring air activation products from a diffuse source (such as the critical assemblies) is difficult, Monte Carlo Modeling (MCNP) was selected as the best method for estimating the radioactive air emissions. ESH-4 initiated a MCNP run for a generic bare critical assembly. The parameters used in this model are given in the following table:

PARAMETER	DESCRIPTION	
Canyon Width	210 m	
Mesa Height	30 m	
Neutron Source Location	center of canyon	
Composition of Air	Element	fraction by weight
	Nitrogen	0.755267
	Oxygen	0.231781
	Carbon	0.000124
	Argon	0.012827
Density of Air	0.0012 g/cc	

The details of the MCNP run are further explained in an ESH-4 memo (ESH-4-MTS-96:081).

The air activation production within a 120-meter hemisphere (approximately 3.6E+12 cc) surrounding a bare critical assembly was evaluated. The radius of 120 meters was chosen for several reasons. First, under stable conditions, air above 120 meters would not reach ground for approximately 20 km. If the stable air velocity was 2 m/s, it would take 2.8 hours for the activated air to reach ground level, as compared to the 1.82 hour half-life of Argon-41, the primary radionuclide of concern. Also, as the radius from the critical assembly increases, the concentration of air activation products would decrease. A summary of the model results is presented in the table at the end of Attachment 2.

Although it was expected that the greatest environmental impact would result from the Argon-41 concentrations in the first 120 meters, the MCNP model was calculated for increments of 250 meters to 2000 meter hemispheres for SHEBA. Only SHEBA was examined for the extended hemispheres because it has a greater neutron fluence than GODIVA IV and SKUA. The model yielded a plot that displays approximately equal ^{41}Ar activities in two hemispheres; the first was 0-120 m and the next was 120-750 m. Although the activity is approximately equal in the two hemispheres, the radionuclide concentration is orders of magnitude less in the higher hemisphere due to the volume differential. Accordingly, associated impacts of extended hemispheres should be orders of magnitude less than those associated with the impacts of the volume of air in the first 120 m. Therefore, the air in the first 120 m would present the greatest environmental impact.

Additionally, as the activated air travels down the canyon, the volume will be dispersed. This would further decrease the concentration of activated air. To support this theory, Gaussian puff dispersion calculations for a cloud released from TA-18 were performed.

Using the number of neutrons from above, the total number of Ar-41 atoms produced was calculated using the following formula:

$$\mathbf{A = \lambda N}$$

where A = Activity (Bq)
λ = decay constant (sec^{-1})
N = number of atoms of Ar-41.

The following conversion was used to report emissions in Ci/yr:

1 Ci = 3.7E10 Bq = 3.7E10 dps.

EXAMPLE SPREADSHEETS FOR CALCULATING AIR ACTIVATION DOSE

Sheba

Date	Energy (amp-sec)	Fissions	Neutrons
1/25/96	1.440E-02	3.888E+16	9.720E+16
2/26/96	1.518E-03	4.099E+15	1.025E+16
2/27/96	1.000E-02	2.700E+16	6.750E+16
2/28/96	5.449E-02	1.471E+17	3.678E+17
4/4/96	3.021E-02	8.157E+16	2.039E+17
8/1/96	1.427E-03	3.853E+15	9.632E+15
12/6/96	1.826E-05	4.930E+13	1.233E+14
12/7/96	4.500E-03	1.215E+16	3.038E+16
12/9/96	1.155E-03	3.119E+15	7.796E+15
12/10/96	3.571E-04	9.642E+14	2.410E+15
12/19/96	modified RAP	2.150E+17	5.375E+17
12/20/96	modified RAP	2.780E+17	6.950E+17
12/21/96	modified RAP	3.000E+17	7.500E+17
TOTAL	**1.181E-01**	**8.118E+17**	**2.030E+18**

Godiva IV

1996 Operation Dates	Energy (ΔT)	Fissions	Neutrons
4-Jan	66.6	1.233E+16	3.08E+16
9-Jan	67.4	1.248E+16	3.12E+16
17-Jan	68.9	1.276E+16	3.19E+16
24-Feb	62.9	1.165E+16	2.91E+16
28-Feb	229.6	4.252E+16	1.06E+17
14-Mar	16	2.963E+15	7.41E+15
20-Mar	67.7	1.254E+16	3.13E+16
21-Mar	265.6	4.919E+16	1.23E+17
3-Apr	68.9	1.276E+16	3.19E+16
11-Apr	56.5	1.046E+16	2.62E+16
25-Apr	77.3	1.431E+16	3.58E+16
30-Apr	74.7	1.383E+16	3.46E+16
30-May	78.1	1.446E+16	3.62E+16
12-Jun	64.6	1.196E+16	2.99E+16
20-Jun	69.6	1.289E+16	3.22E+16
25-Jun	5	9.259E+14	2.31E+15
27-Jun	3.9	7.222E+14	1.81E+15
2-Jul	69.2	1.281E+16	3.20E+16
10-Jul	31.2	5.778E+15	1.44E+16
18-Jul	59.7	1.106E+16	2.76E+16
18-Jul	67.5	1.250E+16	3.13E+16
30-Jul	25.5	4.722E+15	1.18E+16
31-Jul	35.2	6.519E+15	1.63E+16
7-Aug	41.8	7.741E+15	1.94E+16
12-Aug	74.4	1.378E+16	3.44E+16
14-Aug	0.3	5.556E+13	1.39E+14
20-Aug	0.9	1.667E+14	4.17E+14
22-Aug	10.7	1.981E+15	4.95E+15
23-Aug	67.3	1.246E+16	3.12E+16
27-Aug	67.4	1.248E+16	3.12E+16
28-Aug	32.6	6.037E+15	1.51E+16
10-Sep	0.1	1.852E+13	4.63E+13
12-Sep	28.1	5.204E+15	1.30E+16
16-Sep	71.4	1.322E+16	3.31E+16
19-Sep	0.1	1.852E+13	4.63E+13

1996 Operation Dates	**Energy (ΔT)**	**Fissions**	**Neutrons**
25-Sep	38	7.037E+15	1.76E+16
11-Oct	241.7	4.476E+16	1.12E+17
26-Nov	71.1	1.317E+16	3.29E+16
26-Nov	67	1.241E+16	3.10E+16
3-Dec	0.1	1.852E+13	4.63E+13
5-Dec	64.3	1.191E+16	2.98E+16
11-Dec	65.1	1.206E+16	3.01E+16
12-Dec	64.1	1.187E+16	2.97E+16
12-Dec	64.8	1.200E+16	3.00E+16
TOTAL	**2702.9**	**5.005E+17**	**1.251E+18**

Calculation of activity:

	Hemis-phere radius (m)	Neutrons produced in 1996	Decay constant λ (sec^{-1})	Atoms of Ar-41 per neutron (cumula-tive)	Atoms of Ar-41 (cumula-tive)	Radio-nuclide emissions (Ci) (annual)	Additional Ar-41 in next hemisphere (Ci)
GODIVA	120	1.25E+18	1.06E-04	9.04E-05	1.13E+14	**0.324**	
SKUA	120		1.06E-04	9.04E-05		0.00E+00	
SHEBA	120	2.030E+18	1.06E-04	7.72E-05	1.57E+14	**4.48E-01**	
	250			1.14E-04	2.31E+14	6.61E-01	0.21
	500			1.57E-04	3.18E+14	9.08E-01	0.25
	750			1.74E-04	3.53E+14	1.01E+00	0.10
	1000			1.80E-04	3.66E+14	1.05E+00	0.04
	1500			1.83E-04	3.71E+14	1.06E+00	0.02
	2000			1.83E-04	3.71E+14	1.06E+00	0.00
Total 1996 Ar-41 Emissions						**7.72E-01**	